GEOLOGIC SUMMARY

INTRODUCTION The Taurus-Littrow landing site is located on the floor of a gently inclined, east-west-trending, graben-like valley between steep-sided, ancient terra massifs on the southeastern rim of the Serenitatis basin. The valley floor and parts of the adjacent massifs are covered by a youthful dark mantle, a primary objective for sampling by the Apollo 17 astronauts. Additional materials that might be sampled during the mission are those of: 1) closely spaced domical hills that abut the trough on its northeast side, 2) a structure resembling a mare ridge west of the landing site, 3) a ray-like tongue of bright material that extends across the dark blanket from the base of the massif on the south side of the valley, and 4) small, dark-halo craters.

NONCRATER MATERIALS

The terra massifs located north, south, and southeast of the landing area stand about 2,000 m above the valley floor and have slopes of 25° to 30°. Discontinuous ledges, rocky outcrops, boulder tracks, and blocks occur on and at the base of the massifs. Only very young craters are preserved on steep slopes; older craters are apparently obliterated by mass wasting. Slump scarplets are abundant. Another indication of mass wasting is the partial filling of a large crater by debris at the base of the southern massif. These terra massifs are similar to the Apennine Mountains around the Imbrium basin near the Apollo 15 landing site (Carr and others, 1971).

The massifs (unit pItm) probably consist mostly of ejecta from old craters and the major basins in the region, possibly with interlayered volcanic material. Basin ejecta blankets likely to be represented, in order of decreasing age (Stuart-Alexander and Howard, 1970), are those of unidentifiable very ancient basins, Tranquillitatis, Fecunditatis, Serenitatis, Nectaris, Crisium, and Imbrium. The greatest thickness of ejecta is presumably from the closest basin-Serenitatis. Imbrium ejecta may be preserved on the tops of the massifs. Uplift of the massifs by faulting probably began with the Serenitatis event, but repeated uplift has maintained their steep slopes and the sharp topographic breaks at their base. Alternatively the massifs could be volcanic domes, but this interpretation is weakened by: 1) the presence of remnant craters on their tops, and 2) the results from Apollo 15 at Hadley-Apennine (Lunar Sample Preliminary Investigation Team, 1972) and Apollo 16 at Descartes (Apollo Lunar Geology Investigation Team, 1972), which indicate a dominance of

breccias in similar-appearing highland terrain. Hilly material (unit IpIh), distinguished from the massifs principally by lower relief, is widespread north of the landing area and on old crater rims (for example, crater Littrow north of the map area). The hilly material also probably consists of crater and basin ejecta, including some from Imbrium. The morphology of the hilly material is strongly influenced by local structures, as indicated by: 1) the rims of superposed craters which are breached along structural trends; 2) the grooves between hill clusters that follow lineament trends, and 3) assemblages of subparallel scarplets along grooves which suggest that they may be the surface expression of faults. Locally the hilly material may be poorly consolidated, as indicated by the absence of blocks in parts of the northern hills near the landing area, and by secondary craters as young as those from Römer (Scott and Pohn, 1972) which are partly destroyed by mass wasting on slopes. The hilly morphology is thought to originate from disturbances related to basin-forming impacts, differential uplift along fractures, and mass wasting triggered by seismic shaking. This unit is considered similar in origin to the Alpes Formation around the Imbrium basin (Page, 1970; Luc-

The low hills (unit IpIIh) are only slightly elevated above the plains surface. They appear less dissected than the high terra units but have a similar surface texture. They probably represent down-faulted parts of the adjacent mountains, with possible admixtures of mass wasting and ballistic erosion products from the surrounding units. The hill-forming terra units are probably not significantly different lithologically from one another, consisting principally of impact breccias; they differ chiefly in their apparent response to the deformational stresses that have affected the area. Rolling plains material (unit Ipr) occurs within relatively level, low areas

surrounded by higher terra units and in parts of the Littrow valley. In the small valleys within the highlands it probably consists of mass-wasted material. Elsewhere it may be a subdued variant of the low hills (unit IpIlh), or it may be faulted smooth plains material. Another possibility is that it represents a correlative of the terra and plains materials of unknown origin that lie along the margin of the Serenitatis basin farther north and outside the map area (Scott and Pohn, 1972). Smooth plains material (unit Ips) underlies most of the dark mantle on the

relatively planar, eastwardly inclined floor of the Littrow embayment. A pronounced fault scarp and several minor scarps trending about north and facing east disrupt the valley surface. Numerous pits, grooves, and clusters of craters as large as 500 m in diameter appear to be superposed on unit Ips. Ledges of indurated material crop out in the walls of larger craters near the landing site, and blocks that apparently protrude through the dark mantle are strewn over the surface. The evenness of the smooth plains suggests that lavas, possibly mare basalts, which filled the Littrow trough and partially buried low hills there. This occurred mainly after the major episode of faulting of the massifs and before minor later structural adjustments. The smooth plains material may have been emplaced as early as pre-Imbrian time (post-Serenitatis); locally some of this material could be Copernican in age. Superposition relations in the map area are not conclusive. However, an Imbrian age is assigned to the unit on the basis of its general resemblance to plains elsewhere on the Moon. The dark mantle (stipple symbol) covers the valley floor with a deposit that may range from less than a few meters to tens of meters in thickness, and is also found in low areas in the highlands. In some places it appears to consist of small overlapping dark patches, the most pronounced of which are shown with a crosshatch pattern on the map. The dark mantle in highland troughs and locally at the base of the highland scarps may represent reworked dark material mass-wasted from adjacent highs. The ease with which it apparently migrates towards low areas in the highlands indicates that the dark mantle consists of unconsolidated material, draped over pre-existing topography. The absence of resolvable blocks on orbital photographs having 2-m resolution, together with radar data (S. Zisk, oral commun.), implies a scarcity of cobble- and boulder-sized rocks. The dark mantle is most readily interpreted as a pyroclastic deposit, most likely issuing from numerous small (< 10 m) pits and possibly fissures. The lighter tone of the dark mantle to the east of the landing site is apparently caused by numerous small (< 10 m)

bright halo craters, and by outcrops of subjacent light materials in crater walls. The dark mantle may be thinner in this area and contain impactreworked plains material. A middle Copernican age is suggested by superposition relations with sharp, young-appearing craters. Locally a very dark mantle (unit Cvd) overlies other dark units and is most readily recognized in the highlands where it occurs as patches and streaks. It is the freshest feature of the landing area, and is probably of late Copernican age as it covers or contains very sharply defined scarplets and pits. This unit may consist of primary pyroclastic material of that age, or of older material freshly exposed along steep scarps or reworked in crater ejecta. Bright material (unit Cb) extends in a ray-like tongue from the southern

massif northeastward across the valley floor and covers the fault scarp and the main part of the dark mantle. Locally darker parts of the mantle (crosshatch pattern on map) may overlie this bright unit, which has a sharp boundary near its western tip whereas elsewhere it is diffuse. No blocks were observed on the bright mantle, except near its southern edge, but radar data (S. Zisk, oral commun.) indicate that it is coarser than the dark mantle. Many underlying craters seem to maintain their topographic form, attesting to the thinness of the bright mantle. Grooves and ridges occurring on the surface of this mantle near the base of the mountain may be intrinsic. Copernican craters (Cc₅-Cc₆) are superposed, indicating a late middle Copernican age. The bright mantle appears to be an avalanche of loose debris derived from the slopes of the southern massif. It may have been triggered by a cluster of small impacts, or by a violent seismic event. CRATER MATERIALS

In the highlands probable pre-Imbrian, Imbrian, and some Eratosthenian craters are identified only by rim-crest symbols, because it is difficult to make age assignments in this type of terrain. In the less dissected lowlands two Imbrian craters were recognized. Their age assignment is based on morphology; superposition relations with the adjacent plains materials could not be established because the crater rims are covered by the dark mantle. Identifiable Eratosthenian craters in the mapped area are < 1.5 km in size; many unidentified ones are probably represented by the symbol indicating rimless, or low-rimmed depressions Some craters mapped as Eratosthenian in the plains areas are of irregular shape and have relatively shallow floors. They may be of early Copernican age and of secondary origin, possibly from the crater Römer outside the mapped area to the northeast. Early to middle Copernican craters (unit Cce) are mostly covered by the dark mantle but are very common throughout the valley floor and occur in level areas on top of both the southern and northern massifs. Many of these craters, probably of middle Copernican age, are deep, partly of irregular outline, and have a pit or small groove in the center; they may have raised but subdued rims, barely perceptible rims, or no rims. In the vicinity of the landing area northeast-trending crater clusters of probable middle Copernican age consist of two types of craters: larger (200 m to 500 m diameter) individual ones, and smaller (100 m to 200 m diameter) overlapping ones that locally coalesce to form troughs. The clusters are most readily explained as of secondary origin. As no primary crater of suitable size or age is found within the vicinity, they must have originated from a young, large, and distant crater

clusters in both highlands and lowlands indicates that lava collapse pits are unlikely as an origin. Some apparent early to middle Copernican craters have faint dark halos (crosshatch pattern) or very dark halos (unit dh) that are in places centered on crater rims. These craters, especially where they are alined with tectonic trends, could be of volcanic origin and be younger than Late Copernican sharp-rimmed craters having rugged or bowl-shaped interiors, and light (unit lh), dark (crosshatch pattern), very dark (unit dh), or mixed halos are common in the area. Most are small ($< 200~\mathrm{m}$) and have morphologies indicating an explosive origin. As most dark-halo craters are located in areas

an origin as volcanic explosion craters is a distinct possibility.

where some dark material can be observed, they may be impact craters and the dark halo may consist of excavated underlying dark material. However,

STRUCTURE

in the appropriate direction, possibly the crater Tycho. The abundance of crater

The massifs rose along faults transecting the area in northeasterly, northwesterly, and northerly directions. Some of the movement along the faults to maintain the sharp break in slope at their bases, and the sharp grooves with V-shaped profiles between some hills. The sharp break in slope, probably caused by talus at the angle of repose, is located outward from the buried The hilly highland terrain is crossed by grooves and troughs that form lineaments along numerous trends. Old crater rims are breached in places along these lineaments, or are partially offset by normal faults. Vertical tectonic movement must have been pronounced. The location of this area-on or near the rims of several old basins (Tranquillitatis, Crisium, Serenitatis)-may have resulted in the intense shattering of the crust. east-facing scarplets; they probably are faults that may cause some of the easterly inclination of the valley surface. The most pronounced fault extends

The plains area in the embayment is crossed by several small, north-trending, as an east-facing scarp without break from the valley floor into the slopes of the northern massif. Many small splays and scarplets form in echelon patterns along some segments of the fault and cause the mare-ridge appearance of this structure. Relatively recent movement of this fault is suggested by its transection of the rim of an Eratosthenian crater, and by its preservation within steep mountain slopes, where it is only locally obliterated by mass wasting. On the valley floor it appears to be covered by the dark mantle and hence may be older than both the dark and bright mantles. However, an extremely sharp scarplet within the bright mantle may indicate movement postdating deposition of the bright mantle.

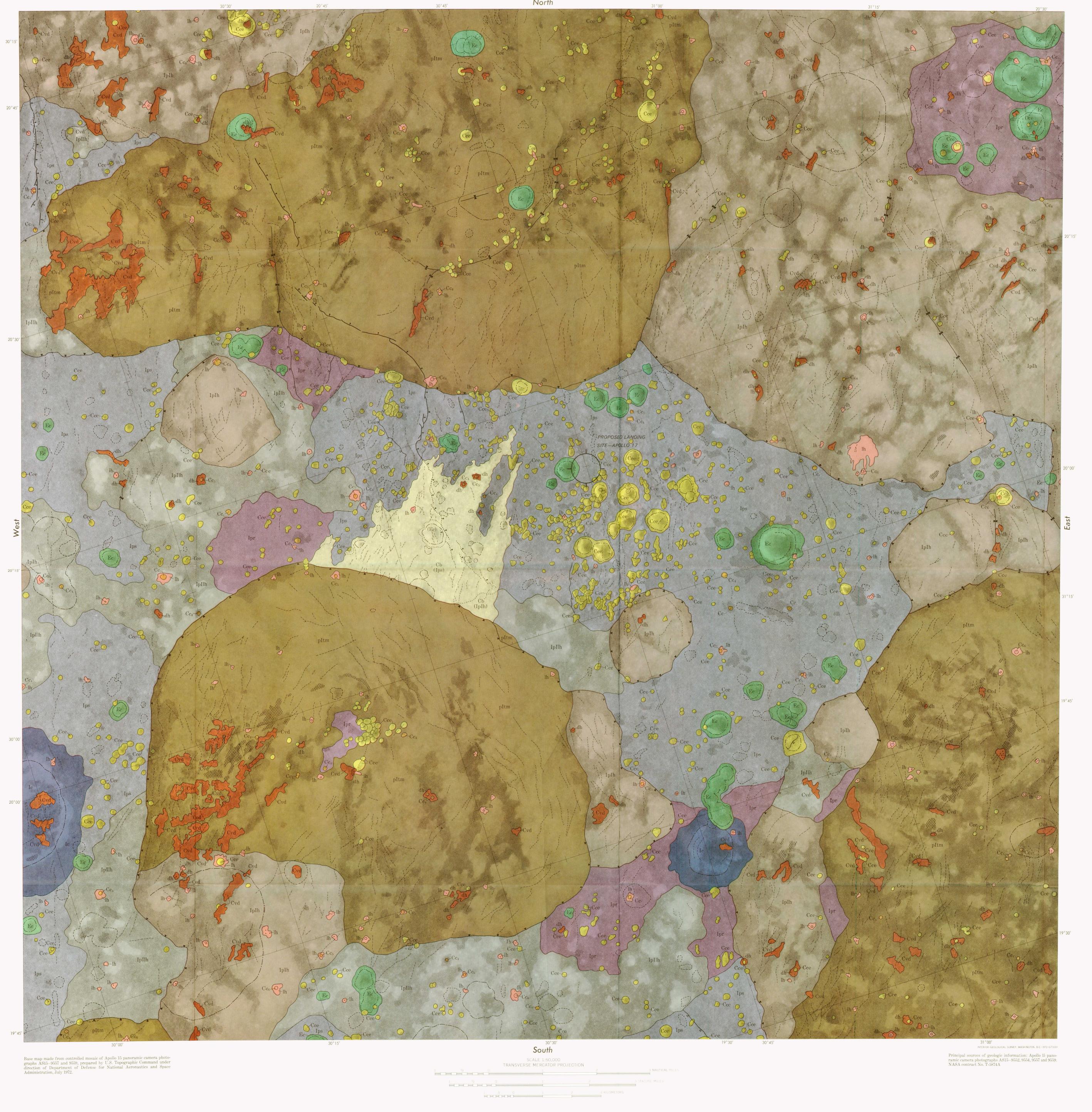
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EXPLANATION CRATER MATERIALS Very dark mantle material Very dark, smooth, fine (< 2 m) material. Mostly small patches and streaks elongated downslope in mountain areas. Locally associated with very small pits and fine, sharp scarps. Indistinguishable from dark halo material. Superposed on other units, including some late Copernican craters Youngest pyroclastic deposit. Associated small pits (< 10 m) and scarps may be vents. Where surrounding late Copernican dark halo craters, may be either volcanic material or impact ejecta Cb Bright mantle material Very bright, ray-like material extending from base of southern massif about 4 km across dark mantle and fault scarp. Sharp to diffuse margin. Craters of late Copernican age superposed, some with dark ejecta. Underlying topography largely unobscured Avalanche of unconsolidated debris triggered by seismic activity or impact. Late middle Copernican age Dark mantle material Smooth, fine (<2 m) material of low albedo covering most of plains in center of area; also in low places elsewhere on map. Generally obscures only very small topographic features. Darker patches common; conspicby crosshatch pattern. Covers early to middle Coperiican craters (Cce, possibly locally Cc₄); late Copernican craters (Cc₅, Cc₆) superposed. Mantles fault scarp in Interpretation Pyroclastic blanket locally transported by mass wasting off steep slopes into adjacent lows. Darker patches indicate younger age or thicker deposit. Around craters they may consist of ejecta of volcanic or impact origin. Early and middle Copernican age, locally may be younger Plains material Cc₆, Cc₅, Cc₄, Cce, Ec, Ic Ipr, rolling plains material. Gently undulating surface. Locally transitional to low hills material (IpIIh). Material of rim, wall and floor of craters > 500 m Generally covered by dark mantle rim-crest diameter. Wall and floor material of craters Ips, smooth, relatively level plains material. Underlies 100 to 500 m rim-crest diameter most of low region in center of map area. Locally pitted Cc₆, sharp, well-defined rim, rugged interior. Pronounced and grooved. Generally sharp break in slope with adjavery bright, or very dark rays or halos Cc5, sharp, well-defined rim, deep, bowl-shaped or rugged interior, light or dark halos Cc₁, rim slightly subdued. Deep, bowl-shaped interior. Rolling plains (Ipr) may be smooth or degraded low Locally faint light or dark halos hills material (IpIIh), or mass-wasting products from Cce, rim subdued to rounded or lacking. Shallow to deep high mountains. Smooth plains (Ips) probably consists interior, some have nit or aroove in center. Craters abo assignment based on similarity with plains material places coalescing to form troughs. Craters of 200 to 500 m diameter in east-central part of map have raised subdued rims, deep interiors, steep bright walls, and some small Cee craters superposed. Except for parts Ec, generally > 300 m diameter, Locally irregular outline. In plains area have low rim, moderately steep wall, and shallow floor. Subdued pit-like depression in highland Hilly material Low hills material Ic, two craters (1.5 km and 3.0 km diameter) in plains Material of low, smooth, mottled Material of closely packed, round, hills with gentle slopes and depres Large crater has finely, concentrically ribbed outside sions, generally < 1 km wide. about 1 km wide; individual hills rim, and steep, bright vertically streaked wall. Smaller Covered by dark mantle except on up to 5 km. Separated by topogracrater subdued hilltops. Occurs mostly near base of phic troughs that locally follow Interpretation high mountains structural lineaments. Troughs Age assignment of craters based on Trask's system commonly contain dark mantle. (1971). Late Copernican craters with halos probably of Downfaulted massif (pItm) and Superposed craters in various impact origin as they have morphologic characteristics of terrestrial impact craters. Light or dark halo comby mass wasting from adjacent have their rims breached to form posed of excavated material. Some very dark halo craters individual hills. Locally transimay be volcanic plains material (Ipr) tional with massif (pItm) and low Cee, early and middle Copernican craters (Cc1-Cc3), hills (IpIlh) materials undifferentiated because covered by dark mantle in Interpretation lowlands and distorted by mass wasting in highlands. Ejecta from surrounding multi-Some with pit-like centers, may be of middle Copernican ring basins including Imbrium, age, or younger and excavated from very soft highland and large old craters; composed of or pyroclastic material. Some may be volcanic vents. complex breccias. Hills result from Clusters and larger deep craters in east center of map intense fracturing, combined with probably secondary craters derived from young, very differential uplift, and mass wastlarge, and distant impact crater. Shallow early and ing. Different morphology from middle Copernican craters may be secondaries to crater massif material (pItm) may reflect Römer. Older craters are assumed of impact origin by different structural history or comanalogy with craters elsewhere on the Moon Terra massif material Generally bright material exposed in high, steep mountains north, south, and southeast of landing site. On steep scarps mottled, bright with ledges and rocky outcrops in places; only small, late Copernican craters superposed. Finely lineated on moderate slopes. Upper surfaces undulating to hilly; craters of all ages superposed, Sharp break in slope at base. Locally transitional with hilly material Interpretation Probably ejecta derived from Serenitatis and surrounding basins and composed of breccias. Uplifted by faulting during Serenitatis and later events. Some individual massifs could be volcanic domes Contact Rim crest Dotted where buried; buried unit in parenthesis Craters > 500 m, old craters, crater remnants, and interred craters Bar and ball on downthrown side; dotted where Depression Rimless or low-rimmed Interpretation: Degraded craters, graben remnants, possibly volcanic craters, locally may be mass wasting, or drainage, pits along faults Sharp groove or gentle swale; may coincide with Interpretation: Probably fault trace lh, light halo Scarp dh, rery dark halo Line at base of slope, barb pointing downslope; solid Small circle or dot locates crater or pit where steep and high; open where gentle or low; Interpretation: Excavated material, possibly locally volcanic material Interpretation: Steep scarp in most places marks Groove, scarplet, ledge, sharp break in slope Outcrop Interpretation: Slump scar, mass wasting trough, Rocky ledges

> MAP OF WEST HALF OF MACROBIUS AND EAST HALF OF MARE SERENITATIS QUADRANGLES SHOWING LOCATION OF DETAILED GEOLOGIC MAPS OF THE APOLLO 17 LANDING AREA

> > 1. Area of 1:250,000 scale map (Scott and Carr 1972) 2. Area of 1:50,000 scale map (Lucchitta, 1972)

GEOLOGIC MAP OF PART OF THE TAURUS-LITTROW REGION OF THE MOON

APOLLO 17 PRE-MISSION MAP